Effects of Recession and Dollar Weakening on the U.S. Agricultural Trade Balance

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1. Introduction

Earlier studies like Krugman and Baldwin (1987) found evidence of a J-curve in the US data, and Carter and Pick (1989) indicated the first segment of the J-curve did exist for the U.S. agricultural trade balance, based on the empirical evidence that a 10 percent depreciation of the U.S. dollar was estimated to lead a deterioration of the agricultural trade balance that would last for about nine months. However in a series of papers Rose and Yellen (1989), Rose (1990) and (1991), not only the J-curve hypothesis was rejected, but also it is argued that there was no significant effect of the real exchange rate on the trade balance for both the developing and the developed countries, including the U.S.

By the same token, Bahmani-Oskoee and Brooks (1999) used the ARDL approach to analyze the US data and found that short-run results supported Rose and Yen (1989) that there was no effect of real exchange rate on the trade balance in the short run, but in the long-run the real depreciation of the US dollar was found to have a favorable effect on the trade balance. Wilson and Tat (2001) on the other hand again by using the Rose and Yellen's model found similar results for Singapore. However Singh (2002) by using a trade balance model *a la* Rose (1991) and an error correction model implied that trade balance of India was sensitive to the real exchange rate changes as opposed to Rose (1990) and (1991). Akbostanci (2002) investigated the existence of a J-curve in the Turkish data in the period of 1987-2000 and suggested the results did not exactly support the J-curve hypothesis in the short-run, yet the short-run behavior of the trade balance in response to real exchange rate shocks showed an S-pattern reminiscent of the Backus et al (1994) rather than the J-curve pattern.

The most recent work of Baek et al. (2009) analyzed the dynamic effects of changes in change rates on bilateral trade of agricultural products between the U.S. and its 15 major trading partners, by applying the ARDL model of the error correction version, which, in the empirical specification is *ad hoc*; they concluded the exchange rate plays a crucial role in determining the short- and long-run behavior of U.S. agricultural trade, but there was no evidence of the J-curve phenomenon for U.S. agricultural products with its major trading partners. However, Baek et al. applied the bilateral trade balance model between U.S. and its 15 major trading partners, which did not specialize the difference among them, since these trading partners include developing as well as developed countries and their historical trading pattern with U.S. could be restricted to internal circumstances such as macroeconomic environment, political changes and national productions etc. Meanwhile, the exchange rate effects on U.S. agricultural trade should be distinguished between these selected countries because different countries have different policies for adjusting exchange rates. Therefore, in our study, we will do the aggregation analysis for U.S. trade balance and select exchange rate index based on world US agricultural trade weighted real rate (where year 2005=100), rather than on the real annual country exchange rates of Baek et al.; and our article will take the recession effects into account, the trade issue becomes different from the macro-economic perspective.

There have been numerous theoretical arguments and empirical analyses in the past decades, and exchange rate and the income growth particularly draw the most attention, yet there is no consistent conclusions to the dynamic effects on U.S. agricultural trade. The general objective of this article is to determine the U.S. agricultural trade pattern during the past decades. The two specific objectives: (a) determine which factor that impacts on agricultural trade balance: exchange rate or income effects? and (b) determine if there is any recession effects on U.S. agricultural trade.

Unlike the previous work by Baek and Koo (2011), we divide U.S. agricultural products into two categories: bulk and high-value goods[2]; in addition, the four times decennial recessions from 1970s to date will be included and examined if each recession had different impacts on U.S. trade of agricultural products. Hence, the two individual commodities plus the combined products will be analyzed for their trade balance between United States and the Rest of World (ROW). Within our sample period, the U.S. trade balance of high-value and combined agricultural goods showed similar pattern especially after 1990s, and both were almost flat since 2008; while the balance of high-valued commodities had been in deficit mostly[3]. Bulk commodities, on the other hand, fluctuated greatly with ups and downs through each time of recession (see Figure 1).

[2] Instead of the three groups of bulk, intermediate and consumer-oriented products categorized by Baek and Koo (2011).
[3] Except in the period from 1992 to 1996, the trade balance of HVP exceeded than 1.

During our sample period, the major oil shock occurred in the early 1980s which is also referred to as a “double-dip” or “W-shaped” recession led to a rising real U.S. interest rate, a decline in import demand, and stagnant growth in many external debt impacted developing countries (see Table 1). And prior to the early 1990s recession, both a devalued dollar and GDP growth helped to rise the U.S. agricultural trade balance, including individual bulk and high-value goods. The Economic Research Service (ERS) reported that since 1995, the exchange rate for U.S. bulk exports was up by nearly twenty percent. The Asian financial crisis that began in July 1997 led to depreciated currencies, decreased economic growth, and depressing global commodity prices, which decreased U.S. agricultural exports. And U.S. agricultural exports value experienced a 23 percent decrease in real terms for the period from fiscal 1997 to fiscal 1999. USDA analysis blamed oversupplies for this decrease, however, the U.S. as a non-crisis exporter experienced a four percent increase in economic growth, decreased producer prices, increased production, increased consumption, decreased exports and increased imports due to the Asian crisis, which included significant depreciations of crisis countries’ currencies.

Over 2000–07, the per capita GDP of U.S. grew by around 1.5% a year, falling below the annual growth of 2.3% during the 1990s; meanwhile, the per capita GDP of the rest of world grew by 2.37% yearly from 2000-07, which was far more than the percentage of 0.88% since 1990s. The spread of the crisis beyond the United States is impacting economic growth throughout the world; the world GDP in 2009 dropped by 4.3%, compared to about 2.5% growth in 2008 and 3% yearly average growth since 1970 (see Figure 2). Our question is how might the decennial economic crisis and ensuing economic downturn affect U.S. agriculture goods over the four decades, especially given how important exports and imports are to the sector?

The economic crisis can have direct and indirect effects on U.S. agriculture. The direct effects come from changes within the U.S. economy alone. The indirect effects will occur from how the crisis impacts foreign income and trade and world energy prices (Liefert and Shane 2009). Seen from Figure 2, before each economic recession mounted there went through a devaluation of U.S. dollar, no matter how long it lasts; between 2002 and 2008 the dollar fell in real terms against all foreign currencies by 18%, 22% and 21% for bulk, high-value and combined agricultural products respectively. However, the crisis’ short-run (current) effect on the U.S. dollar has been, perhaps ironically to appreciate rather than depreciate, yet the appreciation did not last long and reappeared in 2011 again. According to Liefert and Shane (2009), the dollar was appreciating against the currencies of most other countries, developed as well as developing, which means the appreciation could hurt U.S. agricultural exports by making them less price competitive compared to output produced not only by importing countries but also by export competitors, such as Canada, Australia, and Brazil.

The remainder of the article is organized as follows: the next section introduces the theoretical foundation of U.S. agricultural trade balance. Then, the empirical model will be described and the data set used will be discussed, followed by results analysis for both short- and long-run effects on U.S. agricultural trade. And the final section concludes the paper.

2. Theoretical Framework

The theoretical framework for the analysis is based on a simple market model of the agricultural sector. Specifically, we assume competitive market clearing and abstract from complexities associated with product differentiation, imperfect competition, farm programs, and price wedges due to subsidies, tariffs, and trade costs. Exports and imports are assumed to be a function of local currency prices, which adjust in response to changes in the exogenously-determined exchange rate and income in the importing and exporting countries.

With these assumptions, let the agricultural trade balance TB in the initial equilibrium be defined as follows

(1) $$TB = \frac{P_f Q_x}{P_d Q_m} = \frac{P_d Q_x}{P_d Q_m e} = \frac{Q_x}{Q_m \cdot e}.$$

In this equation, P_f is the price of exports expressed in the currency of importing countries; Q_x is the quantity exported from the home market; P_d is the price of imports expressed in the currency of the home market; Q_m is the quantity imported; and $e = DCU/FCU$ is an exchange rate that converts P_f to the currency of home country where DCU is Domestic Currency Unit and FCU is Foreign Currency Unit. Because e tells how many units of domestic currency can be purchased per unit of foreign currency, an increase e implies *devaluation* from the perspective of the home country. An increase in e makes imports more expensive to buyers in the home market, and exports less expensive to buyers in foreign markets whose currencies have strengthened relative to the home market's currency. Equation (1) is consistent with the trade balance relation used to derive the Marshall-Lerner Condition that serves as the theoretical basis for the J-Curve (Rose 1991; Bahman-Oskooee and Ratha 2004). Thus, as a by-product of our analysis of the effects of income on the agricultural trade balance, we show under what conditions the J-curve is likely to hold.

Our analysis begins by expressing equation (1) in proportionate change form

(2) $$TB^* = Q_x^* - Q_m^* - e^*$$

where $X^* = dX/X$. The hypotheses of interest may be stated as follows

(3a) $$\frac{TB^*}{Y_i^*} = \frac{Q_x^* - Q_m^*}{Y_i^*} \qquad i = d, f$$

(3b) $$\frac{TB^*}{e^*} = \frac{Q_x^* - Q_m^*}{e^*} - 1$$

where $Y_i^* = dY_i/Y_i$ is the proportionate change in domestic ($i = d$) and foreign income $i = f$). For the trade balance to increase with an increase in income the sign of equation (3a) must be positive. For the trade balance to increase with an increase in the exchange rate, the sign of equation (3b) must be positive, which implies $\frac{(Q_x/Q_m)^*}{e^*} > 1$.

Whether our model satisfies the foregoing conditions can be determined from the reduced form for trade balance (see appendix for derivation)

(4) $$TB^* = \overbrace{\left(\frac{(\eta_x - \varepsilon_m)k_d\gamma_d}{\varepsilon - \eta}\right)}^{-} Y_d^* + \overbrace{\left(\frac{(\varepsilon - k_d\eta_d - k_x\varepsilon_m)\gamma_x}{\varepsilon - \eta}\right)}^{?} Y_f^* + \overbrace{\left(\frac{(\eta_x - \varepsilon_m)(k_m\eta_m - k_x\eta_x)}{\varepsilon - \eta} - 1\right)}^{?} e^*.$$

The Greek symbols indicate elasticities and the *k* terms indicate quantity shares. Specifically, η_d (< 0) and η_x (< 0) are price elasticities of domestic and export demand; ε_d (> 0) and $\varepsilon_m > 0$ are price elasticities of domestic and import supply; γ_d (> 0) and γ_x (> 0) are income elasticities of domestic and export demand; $\eta = (k_d\eta_d + k_x\eta_x) < 0$ is the overall price elasticity of demand; $\eta_m = \frac{k_d\eta_d + k_x\eta_x - k_s\varepsilon_d}{k_m} < 0$ is the price elasticity of import demand; $\varepsilon = (k_s\varepsilon_d + k_m\varepsilon_m) > 0$ is the overall price elasticity of supply; $k_s = Q_s/(Q_s + Q_m)$ is the share of domestic supply that comes from domestic production; $k_m = Q_m/(Q_s + Q_m)$ is the share of domestic supply that is imported; $k_d = Q_d/(Q_s + Q_m)$ is the share of domestic supply that is consumed in the home market; and $k_x = Q_x/(Q_s + Q_m)$ is the share of domestic supply that is exported.

Given the sign restrictions on elasticities, the only variable to have a determinate effect on trade balance is domestic income. Specifically, market theory predicts that an isolated increase in domestic income will reduce the trade balance, i.e., cause export value to fall in relation to import value. No such predictions are forthcoming about isolated movements in either foreign income or the exchange rate. Thus, there is little *a priori* reason to believe that improvements in income, whether domestic or foreign, will improve the trade balance. The same is true for devaluation.

The Marshall-Lerner Condition (MLC) states that $\frac{TB^*}{e^*} > 0$ if $(\eta_x + |\eta_m|) > 1$. If the trade balance is to improve in response to devaluation, import demand must be more price elastic than export demand. The MLC implicitly assumes import supply is perfectly elastic and import share equals export share. To see this, note that equation (4) reduces to

$$(5) \qquad TB^* = \overbrace{\left(\frac{-k_d\gamma_d}{k_m}\right)}^{-} Y_d^* + \overbrace{\left(\frac{(k_m - k_x)\gamma_x}{k_m}\right)}^{?} Y_f^* + \overbrace{\left(\frac{(k_x\eta_x - k_m\eta_m)}{k_m} - 1\right)}^{?} e^* \qquad (\varepsilon_m = \infty).$$

The coefficient of e^* is positive when $\left(\frac{k_x}{k_m}\eta_x + |\eta_m|\right) > 1$. This condition reduces to the MLC when $\frac{k_x}{k_m} = 1$. If demand elasticities are smaller in the short run than in the long run, $(\eta_x + |\eta_m|)$ might be less than 1 immediately following devaluation, only to become greater than 1 after sufficient time has elapsed for domestic and foreign buyers to adjust fully to the devaluation. In this situation, and with the added assumption that import supply is perfectly elastic, devaluation could cause the trade balance initially to decline before it improves, tracing a J-shaped curve. However, perfectly elastic import supply implies demand shocks have no effect on price, which is not a plausible hypothesis for a large importer of agricultural products like the United States. Thus, the relevance of the J-curve hypothesis for the U.S. agricultural trade balance is dubious. In any event, standard market theory provides no hypotheses about the effects of changes in foreign income and the exchange rate on trade balance. Theory has predictive content only with respect to domestic income, and in that case the trade balance is expected to improve (deteriorate) when income falls (rises).

In the econometric literature trade relations typically are estimated with the dependent variable defined as trade value rather than trade quantity (e.g., Baek and Koo, 2011). The relevant reduced-form equations in this instance are (see appendix)

$$(6)\qquad V_x^* = \overbrace{\left(\frac{(1+\eta_x)k_d\gamma_d}{\varepsilon-\eta}\right)}^{?} Y_d^* + \overbrace{\left(\frac{(k_x+\varepsilon-k_d\eta_d)\gamma_x}{\varepsilon-\eta}\right)}^{+} Y_f^* + \overbrace{\left(\frac{k_m\varepsilon_m-\eta_x(k_x+k_s\varepsilon_d-k_d\eta_d)}{\varepsilon-\eta}\right)}^{+} e^*$$

$$(7)\qquad V_m^* = \overbrace{\left(\frac{(1+\varepsilon_m)k_d\gamma_d}{\varepsilon-\eta}\right)}^{+} Y_d^* + \overbrace{\left(\frac{(1+\varepsilon_m)k_x\gamma_x}{\varepsilon-\eta}\right)}^{+} Y_f^* + \overbrace{\left(\frac{\varepsilon_m(k_m-k_s\varepsilon_d+k_d\eta_d)-k_x\eta_x}{\varepsilon-\eta}\right)}^{?} e^*.$$

Market theory predicts that an increase in foreign income increases the value of a home country's exports and imports alike. An increase in domestic income increases the value of imports, but may increase or decrease the value of exports depending on whether export demand is inelastic or elastic. Devaluation increases the value of exports, but may increase or decrease the value of imports depending on sensitivity of domestic producers and consumers to price in relation to import share.

3. Empirical Model

To test the hypothesis that the domestic income growth has a negative effect on the U.S. agricultural trade balance, we follow Baek *et al*. (2009) and replicate their work with employing an autoregressive distributed lag (ARDL) modeling approach. The ARDL approach avoids spurious regression associated with non-stationary time series, and permits distinguishing short-run from long-run effects. The ARDL approach lends itself to the present problem in that the equation to be estimated, namely $TB = TB(Y_d, Y_f, e)$, is in reduced form, thereby avoiding problems associated with endogenous right-hand-side variables (Pesaran and Shin 1999).

The first step is to specify the long-run equilibrium relationship. For this purpose, we adopt the constant elasticity specification

$$(34)\quad \ln TB_{i,t} = \alpha + \beta_1 \ln Y_t^{US} + \beta_2 \ln Y_t^{ROW} + \beta_3 \ln ER_{i,t} + \varepsilon_{i,t},$$

where *i* indexes the type of agricultural product (1 = bulk, 2 = high value, and 3 = combined bulk and high value); *t* indexes the year (1976-2012); TB_{it} is the U.S. trade balance defined as the real value of U.S. exports divided by the real value of U.S. imports; Y_t^{US} is real U.S. per capita GDP;

Y_t^{ROW} is real per capita GDP for world less US (in U.S. dollars); ER_{it} is the real trade weighted exchange rates between the United States and the currency of foreign trading partners for U.S. bulk products, U.S. high-value products, and combined bulk and high-value products, respectively[4]; and ε_{it} is the error term. The exchange-rate variables are defined as U.S. dollar divided by Foreign Currency Unit (*ER* = DCU/FCU). Hence, an increase in *ER* implies domestic currency *devaluation*.

The betas are long-run elasticities. Theory predicts $\beta_1 < 0$ (a rise in domestic income will increase imports and reduce exports, causing *TB* to decline). Intuitively, a rise in foreign income and a weaker domestic currency should each improve the trade balance, implying positive signs for β_2 and β_3. However, as we saw in the theoretical analysis, intuition is correct only under certain conditions. The signs of β_2 and β_3 are an empirical issue.

The second step is to write the long-run equilibrium relation in ARDL form

(35) $$\Delta \ln TB_{i,t} = a + \sum_{k=1}^{p} b_k \Delta \ln TB_{i,t-k} + \sum_{k=1}^{p} c_k \Delta \ln Y_{t-k}^{US} + \sum_{k=1}^{p} d_k \Delta \ln Y_{t-k}^{ROW} + \sum_{k=1}^{p} e_k \Delta \ln ER_{i,t-k} + \gamma_1 \ln TB_{i,t-1} + \gamma_2 \ln Y_{t-1}^{US} + \gamma_3 \ln Y_{t-1}^{ROW} + \gamma_4 \ln ER_{i,t-1} + d_1 + d_2 + d_3 + d_4 + u_{i,t}$$

where Δ is the difference operator, *p* is the lag order, *dummy* variable of d_1 represents 1 during the recent recession period of 1980 to 1982 otherwise 0, and d_2 represents 1 within the second recession period of 1990-1991 otherwise 0; d_3 would be 1 during the third recession at the year of 2001 otherwise 0; d_4 indicates 1 in the most recent recession period from 2007 to 2009 and otherwise 0; $u_{i,t}$ is a serially uncorrelated error term. The F-test will be used for examining if there are different effects among the decennial recessions during our sample period (the null hypothesis is:$d_1 = d_2 = d_3 = d_4 = 0$).

[4] According to the Economic Research Service (2001), nominal exchange rates are those observed and are a result of the market and other forces out of our control. Real exchange rates are nominal rates adjusted for inflation. Trade weighted exchange rates are calculated with a trade-weight index. These indices are constructed by multiplying the average trade weight of a country in U.S. exports, exports to the world, and U.S. imports. These weights are average dollar shares of U.S. exports, exports to the world, and U.S. imports for the relevant commodity. The current exchange rate for each country (in units per dollar) is then adjusted by taking the ratio of the same period CPI in the U.S. to the country in question. The percent change from the base period is then multiplied by the weight. These weighted changes are summed into a total, which is the “real” index.

Furthermore, the terms involving the gamma parameters constitute the error-correction term EC_{t-1}. Equation (35) is called the error-correction form of the ARDL model (Baek *et al*., p. 218). The gammas represent the long-run (cointegrating) relationship. The coefficients of following the summation symbols indicate short-run effects. The existence of a level relationship (cointegration) is determined by testing the null hypothesis $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ using the asymptotic F-values tabulated by Pearson, Shin and Smith (2001). If the null hypothesis is rejected, the variables are cointegrated. If test results are inconclusive, the ARDL model is re-specified with an error correction term. If the estimated coefficient of EC_{t-1} is negative and significant, the variables in the trade balance relation are said to be cointegrated. The tests are valid even if the regressors are not integrated to the same order (e.g., *I*(0) or *I*(1)). For details, see Baek *et al*. (2009) and the references therein.

The empirical analysis is completed by estimating separate equations for exports and imports. The ARDL specifications are identical to equation (35) except that the *TB* variable is replaced with *EX* and *IM* to represent, respectively, export value and import value.

4. The Data and Testing Procedure

We apply annual data over the period 1976 to 2012. Because of the limitations of the data to annual series, the more dynamic aspects that would be present in quarterly or monthly data may not be identified at this stage. The total values of exports and imports for agricultural products between the United States and rest of the world (ROW) are collected from the Foreign Agricultural Trade of the United States (FATUS) database of the U.S. Department of Agriculture (USDA). Different from the previous work, the U.S. trade balance in this analysis is expressed as the ratio of real value of U.S. exports to real value of U.S. imports with the ROW. In that it is not sensitive to the units of measurement by using the ratio and hence can be interpreted as the real trade balance (Baek et al., 2009); meanwhile, the ratio can narrow the range of the variable to make it less susceptible to outlying or extreme observations (Wooldridge 2000).

The real gross domestic product (GDP) index (2005=100) is used as a proxy for the real income of the United States and ROW which is obtained from the Economic Research Service (ERS) and real trade weighted exchange rates for U.S. bulk and high value products are both from FAS while the world U.S. agriculture trade weighted real exchange rate is from ERS

International Macroeconomic Data Set. Since the exchange rate is defined as the number of domestic currency (U.S. dollars) per unit of foreign currency in this article, an increase in the exchange rate implies a depreciation of the U.S. dollar from the domestic consumers' perspective and a currency strengthening from the foreign buyers' perspective.

As Pesaran, Shin, and Smith (2001) note, it is crucial to balance between choosing *p* sufficiently large to mitigate the residual serial correlation problems and sufficiently small so that equation (35) is not unduly over-parameterized, particularly in view of the limited time-series data which are available (Pesaran, Shin, and Smith 2001, p. 308). Hence, we employed the Akaike Info Criterion (AIC) for lag selection.

With the selected lag orders, we then test the existence of a level relationship (counteraction) among variables. For this purpose, the null hypothesis of no level relationship, namely (γ_1=γ_2 = γ_3 = γ_4= 0) in equation (35) is tested, irrespective of whether the regressors are purely *I* (0), purely *I* (1), or mutually cointegrated. Pesaran, Shin, and Smith (2001) used an *F*-test with two sets of asymptotic critical values in which all the regressors are assumed to be purely *I* (0) or purely *I* (1). This is called a "bounds testing" procedure since the two sets of critical values provide critical value bounds for all possibilities of the regressors into purely *I* (0), purely *I* (1), or mutually cointegrated (Pesaran, Shin, and Smith 2001, p. 290). With *k* = 3 for the U.S. bulk, high-value and combined agricultural products, for example, the *F*-statistic value is around 5.0, 4.1, and 10.7 respectively, which all lies outside the upper level of the 10 percent critical bounds (See Table 2). As a result, the null hypothesis that there is no cointegrated trade balance equation can be rejected, irrespective of whether the regressors are purely *I* (0), purely *I* (1), or mutually cointegrated. Also, to provide the further evidence of cointegration, the error-correction terms in the ARDL model can be used to determine the existence of cointegrated trade balance equations following Kremers, Ericson, and Dolado (1992) and Banerjee, Dolado, and Mestre (1998). Hence, a negative and significant lagged error-correction term would imply the variables be cointegrated.

5. Empirical Results

In table 3, none of the coefficient estimates show the negative sign at the current period and positive signs in the following three lag period. Or rather, the last one or two lagged variables show statistical significance for all the three categories, which might imply that in the short run the exchange rate not be the dominating factor in U.S. trade to ROW, and our results do not exactly hold for the J-curve pattern. Likewise, previous studies found that the short-run behavior of the trade balance in response to real exchange rate shocks cannot agree to the J-curve hypothesis either (e.g. Backus et al. 1994, Bahmani-Oskooee and Ratha 2004, Baek et al. 2009); partly it was because the dollar wasn't strong for the reason it normally would have been-because of a strong international trade position. Instead, it was strong because a huge sum of foreign investment money was flowing into the U.S. seeking "safe haven" investments and because of the high rates of return available because of high interest rates in the U.S. compared to the rest of the world. Thus, devaluing the dollar did not change that significantly (Pool and Stamos, 1990). Beyond that, during the period of 1980s, while the dollar did fall against some U.S. trading partners, e.g. Japan and West Germany, it did not fall against others, such as the newly industrialized countries of Taiwan and South Korea and the Pacific Rim countries[5]. Before the first recession within our sample period, the exchange rate line reached peak for all the three groups, which means the dollar against ROW currency was devalued to the most extent, and the U.S. trade surplus of bulk and combined goods hit the highest point in the following year. However, till the last year of the sample period, the trade surplus of combined agricultural products fell by 34 percent compared to its initial value, and the value of bulk goods even decreased about 70 percent though going through ups and downs. Only the trade deficit of U.S. high-value products improved by 36 percent over the past four decades (See Figure 1).

It should also be pointed out that the coefficients of the error-correction terms are all negative for bulk products, high-value products and the combined agricultural products, and all

[5] Since 2000, U.S. goods imports from developing countries have exhibited higher growth (almost 4 times as much) than that from industrial countries, 130 percent compared with 36 percent. On the other hand, U.S. goods exports to developing countries have grown almost three times as fast as U.S. goods exports to industrial countries, 135 percent compared to 54 percent. Due to this long-term higher-growth difference, the share of U.S. goods exports to developing countries have grown from 45 percent in 2000 to 55 percent in 2011. For example, the percentage change of U.S. exports to China reached 554% versus that of U.S. imports from China was 300.2% from 2000-11.

are statistically significant at least at the level of 10 percent. For the U.S. bulk and combined agricultural products, the speed of adjustment towards equilibrium would both be around 80 percent, and for high value products, the speed towards equilibrium is about 30 percent, which further provides evidence of the existence of the long-run relationship among variables (Kremers, Ericson, and Dolado 1992, Banerjee, Dolado and Mestre 1998, and Baek et al.2009). The findings further justify the ARDL modeling of U.S. agricultural trade of all the three categories with ROW, in which the F-statistics results are cointegration (See Table 2).

Table 4 yields the estimated results from the full model before any F-tests for recession effects, and the coefficient estimates of trade weighted real exchange rate carry the positive relationship with the U.S. trade balance for all the three products; at meanwhile, high-value and combined agricultural products are statistically significant at the 5 percent level (Table 4). It states that the depreciating domestic currency (U.S. dollars) lead to an improvement of U.S. trade balance in the long term, meaning with each one percent of U.S. dollar depreciation, U.S. trade balance of high-value commodities and total agricultural products would enhance by 1.62 percent and 1.88 percent respectively. Besides, for both of high value and combined products, the U.S. trade balance displays the positive relationship with domestic income and negative with foreign income, where only trade balance of combined goods with foreign income shows statistical significance at the level of 5 percent. According to Baek et al. (2009), it demonstrates that a rise of real domestic income increases the domestic demand for U.S. exports while decreases the demand for foreign imports, thereby improving the U.S. trade balance; and vice versa, for the foreign income, it has adverse relationship with the U.S. trade balance and a deteriorating effect accordingly. One of the possible explanations for the finding is that, since imports are defined as the difference between domestic consumption and production, an increase in domestic income could increase the domestic production of import-substitute commodities faster than a rise in domestic consumption, thereby leading to the reduction of domestic imports[6]; meanwhile, records show HVP exports exceeded exports of bulk products at the beginning of year 1990 for the first time and kept the trend until today, then the income effects of HVP could be the major contributor and thus one percent increase of foreign GDP, *ceteris paribus*, would

[6] See Magee (1973), Bahmani-Oskooee (1985), and Bahmani-Oskooee and Ratha (2004)

decrease the U.S. trade surplus of combined agricultural goods by around 1.32 percent[7]. Furthermore, our results found that growth in incomes has a larger effect on exports of bulk commodities than on high-value exports, which is opposite to the finding drawn by Shane et al. (2009).

Compared to the recent work by Baek and Koo (2011), our results indicate the similar results on the U.S. import side but different on the export side in the long run. That is, the U.S. exports are very responsive to exchange rate changes for bulk, high-value (consumer-oriented products) and the combined commodities but do not seem to respond much to income; And for U.S. imports, both of bulk and high-value products are relatively insensitive to exchange rate changes.

As for dummy variables of recessions, F-test indicates that only trade balance model and import model of U.S. combined agricultural products reject the null hypothesis that the four dummy variable coefficients are zero, which means the U.S. recessions occurred in the past forty years have had different effects on trade balance as well as imports of U.S. combined products. And the dummy variable effects imply that the U.S. trade balance would decrease by 0.21 percent during the 1980s crisis compared with other years, while the U.S. imports would increase by 0.15 percent within the recent great recession from 2008 to 2009. This might suggest that when the first economic recession of our sample period occurred, the U.S. trade balance of combined agricultural goods decreased, meaning U.S. exports declined or U.S. imports increased or both. One possible reason should be correlated with decreasing U.S. GDP declining: Table 4 demonstrates the U.S. income is positively related with its trade balance and negatively related with its imports for combined products, therefore U.S. trade balance would be hurt and U.S. imports would increase under such a circumstance. Another reason could be the U.S. dollar was getting strong instead of weakening (or devaluation) in both recession periods, the 1980s recession and the most recent recession, during which the exchange rate curve of combined agricultural goods started to slump seen from Figure 2, thus, the U.S. exports became decreasing

[7] Stephen (ERS, USDA, 2013) introduced the market share of middle-income and high-income countries that import from U.S. Agricultural products, and they now account for the largest share of U.S. agricultural exports of both bulk products and semi-processed high-value products (*e*.g. wheat, soybeans, and soybean meal); while for the other categories of high-value products---raw products and processed products, high-income countries remain the largest U.S. markets, followed by the upper middle-income countries.

and imports increasing correspondingly. Besides, the most recent recession was verified to positively impact on U.S. imports, which further states that the recession could increase the imports. And our results agree to the previous work by Liefert and Shane (2009) mentioned earlier. For individual agricultural goods such as bulk or high-value products, F-tests indicate that none of the recessions has any significant impact on U.S. trade balance. This might imply that global trade partners have tended to constrain exports/imports to the U.S. combined agricultural products rather than to individual ones in response to recessions, and basically the U.S. recession effects for agricultural trade in the last forty years were less than expected and the U.S. monetary policy or financial tools for mitigating the recession downturns should have worked to certain extent.

Specifically, the export and import equations are estimated separately for further analysis. The results suggest that the U.S. exports have a positive relationship with the exchange rate in long-run for three cases, and all of the estimates are statistically significant at least at level of 5 percent, highly suggesting that the devaluing domestic currency (U.S. dollars) would increase the domestic (U.S.) exports; meanwhile, in the long term, the real exchange rate is passed through to the U.S. exports of combined agricultural products to the largest degree, compared with individual bulk and high-value goods. Besides, for bulk commodities the relationship between U.S. exports and foreign income appears positive and statistically significant at the level of 10 percent, rather than the other two cases; and one percent increase of foreign per capita GDP would enhance U.S. bulk exports by around 3.57 percent, while one percent of increase of traded weighted real exchange rate would improve U.S. exports by 1.19 percent, which corroborates the conclusion drawn by Shane et al. (2009) that the net effect on total agricultural exports depends on the magnitude of growth in income compared to the magnitude of change in the trade-weighted exchange rate.

By contrast, the reduced import model implies that the real exchange rates of all the three categories are negatively related with the U.S. imports, but only the coefficient of combined agricultural goods shows significance at 10 percent level, corroborating the common-held belief that the devalued U.S. dollar would cause U.S. imports to decline, which is consistent with our hypothetical expectations. The decomposed export model and import model demonstrate the depreciation effects of exchange rate on U.S. trade outweigh the inconclusive effects of either domestic or foreign income in the long run.

As beginning with the pioneering studies of Bahmani-Oskooee and Ardalani (2006, 2007), there has been a growing body of literature that argues that trade balance study could suffer from aggregation bias of data due to the fact that a country tends to export and import different commodities to/from different trading partners, thus in this article we did the *Wald* tests to determine whether or not bulk and high-value commodities can be aggregated across three models (See Table 5). The results show that all the three null hypotheses are rejected at 5% probability level, which means there might not exist any aggregation bias between bulk and high-value in our study.

As for the F-tests for determining whether recession effects are jointly significant, only combined agricultural goods receive some support in that two of the nine tests show a significant relationship between U.S. import value or trade balance and the recession effects during the past decades. However, the remaining tests show no significance (See Table 6).

Though not all the estimated coefficients for the three cases are statistically significant, the signs between exchange rates and U.S. trade balance are the same; according to the earlier mentioned theoretical deductions, the relationship between foreign income and U.S. trade balance is ambiguous and cannot be inferred. Thus, our results might provide empirical evidence, if any, for the previous theoretical argument. Generally speaking, the estimates of real exchange rates present positive relationship with U.S. trade balance not only for individual agricultural commodities of bulk and high-value goods but also for the combined agricultural products within the sample period since late 1970s.

Finally, to test if the estimated coefficients are stable or not over time, we use the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests to the residuals of ECMs (Eqs. (35). For stability of all estimated coefficients, the plot of these two statistics should stay within the 5% significance level. The overall results of stability test suggest that the estimated coefficients of all models are generally stable over the sample period[8].

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[8] According to Baek and Koo (2011), these tests are known to have low power and could miss important breaks.

6. Conclusions

The article applies the dynamic ARDL model of error correction version, not only investigating if there is J-curve effect in the short-run or not, but also taking a deep analysis for U.S. recession effects and exchange rate as well as income growth effects in the long run on the U.S. trade balance of agricultural commodities which mainly consists of bulk products and high-value products. Our results indicate that there is no significant J-curve effect for three cases, while the long-run effect demonstrates that the domestic currency devaluation is positively related with U.S. agricultural trade balance for bulk, high-value and combined agricultural products, though the high-value products appear the more modest effects compared to the other two.

In sum, the real trade-weighted exchange rate is found to be the key determinant of U.S. agricultural trade balance in the long-term, rather than domestic or foreign income. We find that the three categories of agricultural products do indeed respond differently to exchange rate and income. For bulk and high-value products, U.S. exports are highly sensitive to exchange rate and foreign income, while U.S. imports barely respond. For combined agricultural products, on the other hand, U.S. exports respond greatly to exchange rate, and U.S. imports behave significantly with respect to both of changes in exchange rate and foreign income; besides, the 1980s recession had significant effects on U.S. trade balance while the most recent recession had great impact on U.S. imports, showing the U.S. trade with ROW partners was mainly influenced by the two times economic crisis during our sample period.

To our knowledge, it is the first time that the ARDL model is applied for the recession effects on individual groups of U.S. total agricultural commodities: Bulk and High-Value products. Different from the previous work by Baek and Koo (2011), this paper analyzes both of dollar devaluation impacts and the decennial U.S. economic recession effects on U.S. trade balance by employing the aggregated data and explores the reasons that the J-curve effect did not show up during the past decades; also, the test shows that there is no any aggregation bias between bulk and high-value in our study, making both of the dynamic short-run effect and stable long-run effect estimated from the reduced model at linkage with the theoretical structure equations more solid and convincing.

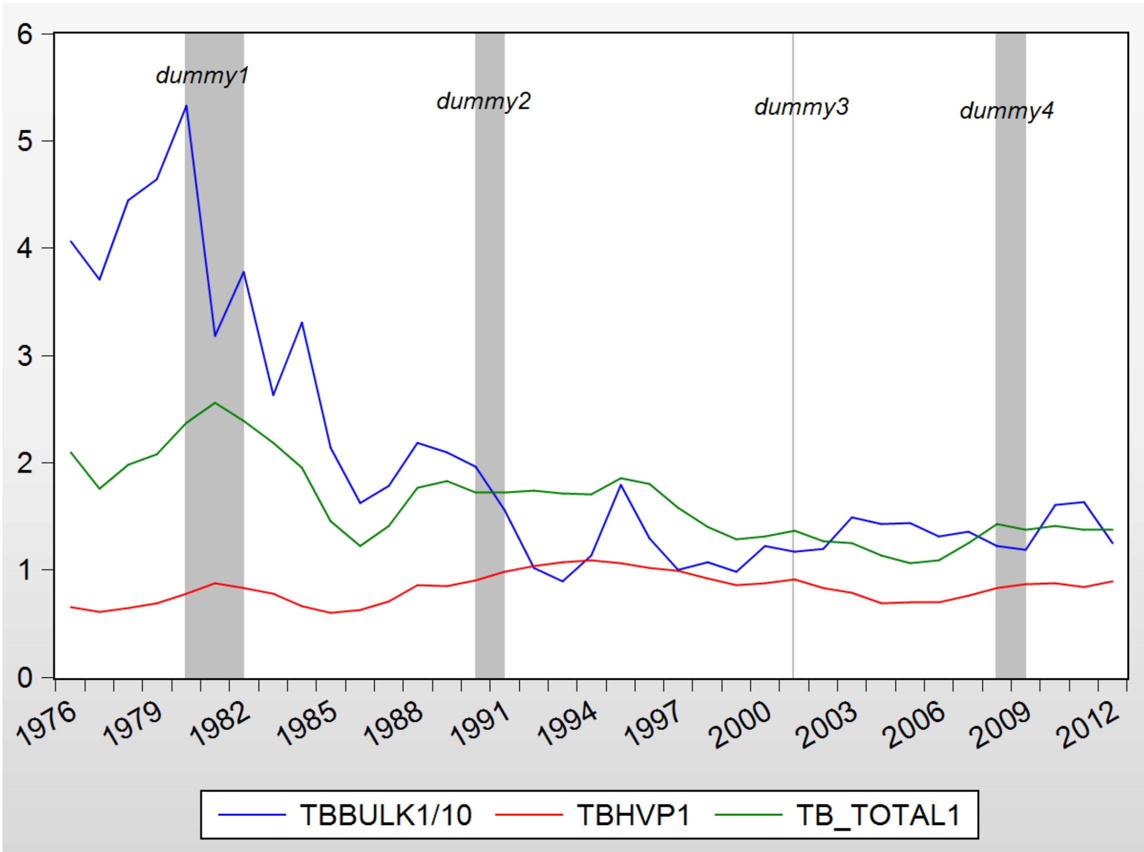
Table 1. The Descriptive Summary of Economic Recession from 1976 to 2012.

Name	Dates	Duration (months)	Peak Unemployment	GDP decline (peak t trough)	Characteristics
Early 1980s recession	1980-1982	1 year 10 months	10.80%	−2.7%	The recession began as the Federal Reserve, under Paul Volcker, raised interest rates dramatically to fight the inflation of the 1970s.The Iranian Revolution sharply increased the price of oil around the world in 1979, causing the 1979 energy crisis. This was caused by the new regime in power in Iran, which exported oil at inconsistent intervals and at a lower volume, forcing prices up. Tight monetary policy in the United States to control inflation led to another recession. The changes were made largely because of inflation carried over from the previous decade because of the 1973 oil crisis and the 1979 energy crisis The early '80s are sometimes referred to as a "double-dip" or "W-shaped" recession.
Early 1990s recession	July 1990-Mar1991	8 months	7.80%	−1.4%	After the lengthy peacetime expansion of the 1980s, inflation began to increase and the Federal Reserve responded by raising interest rates from 1986 to 1989. This weakened but did not stop growth, but some combination of the subsequent 1990 oil price shock, the debt accumulation of the 1980s, and growing consumer pessimism combined with the weakened economy to produce a brief recession
Early 2000s recession	March 2001-Nov2001	8 months	6.30%	−0.3%	The 1990s were the longest period of growth in American history. The collapse of the speculative dot-com bubble, a fall in business outlays and investments, and the

					September 11th attacks brought the decade of growth to an end. Despite these major shocks, the recession was brief and shallow. Without the September 11th attacks, the economy might have avoided recession altogether.
Great recession	Dec 2007-June 2009	1 year 6 months	10.00%	−4.3%	The subprime mortgage crisis led to the collapse of the United States housing bubble. Falling housing-related assets contributed to a global financial crisis, even as oil and food prices soared. The crisis led to the failure or collapse of many of the United States' largest financial institutions: Bear Stearns, Fannie Mae, Freddie Mac, Lehman Brothers, Citi Bank and AIG, as well as a crisis in the automobile industry. The government responded with an unprecedented $700 billion bank bailout and $787 billion fiscal stimulus package. The National Bureau of Economic Research declared the end of this recession over a year after the end date. The Dow Jones Industrial Average (Dow) finally reached its lowest point on March 9, 2009.

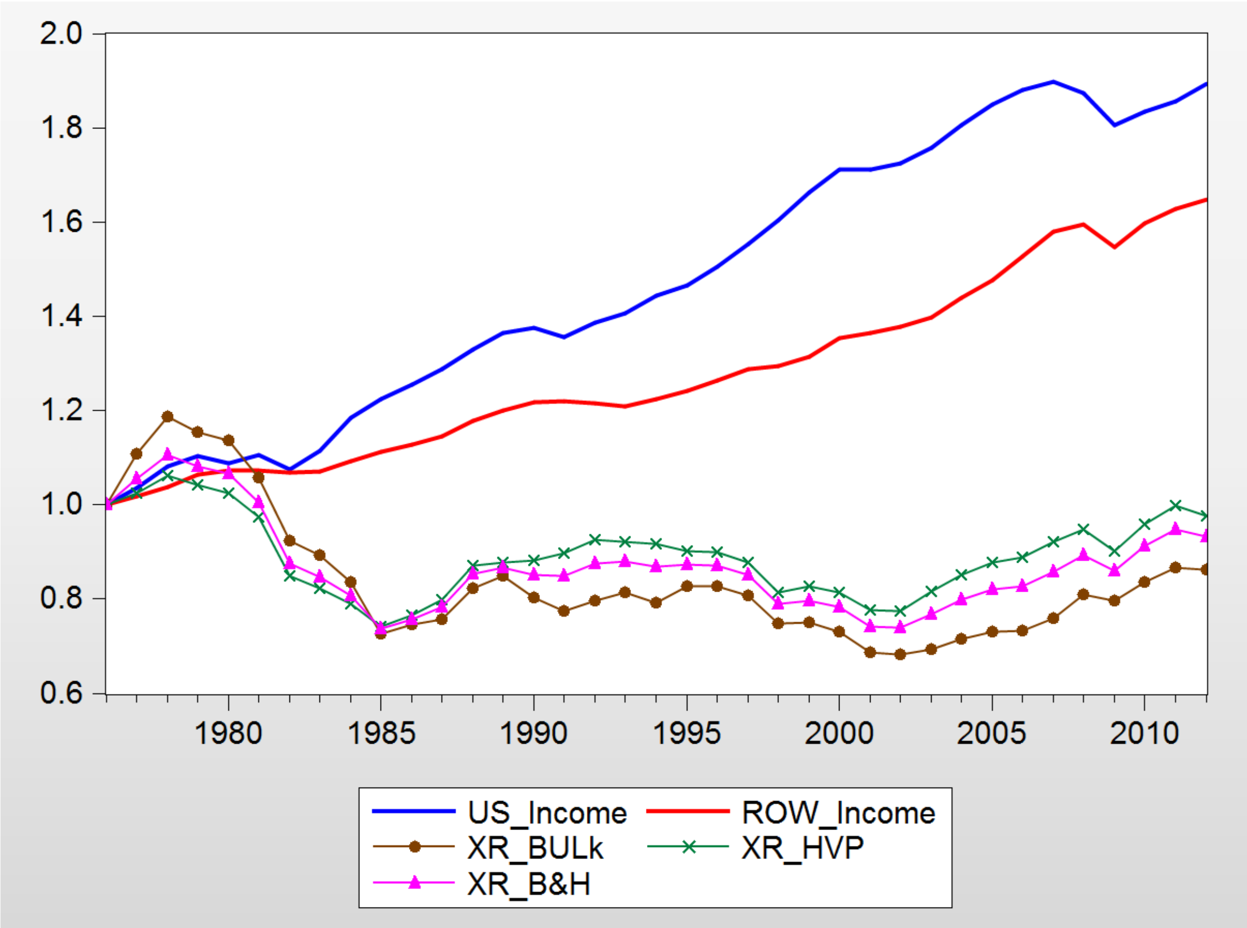
See wiki link of http://en.wikipedia.org/wiki/List_of_recessions_in_the_United_States#Free_Banking_Era_to_the_Great_Depression

Figure 1. Trade Balance Ratio for U.S. Bulk products and Real Trade Weighted Exchanges Rates for U.S. Bulk products, HVP and Combined agricultural goods. (2005=100)



Source: FAS, USDA

Figure 2. Domestic Income, Foreign Income and Real Trade Weighted Exchanges Rates for U.S. Bulk, High Value and the combined products respectively from 1976 to 2012 (1976=1).



Source: FAS, USDA, and ERS International Macroeconomic Data Set

Table 2. Results of F-Test for Cointegration among Variables of Reduced Trade Balance Model.			
Variable	AIC Lags	*F*-statistic	Decision
Bulk	5	5.03	Cointegration
High-Value	4	4.11	Cointegration
Combined	3	10.66	Cointegration

Note: A lag order is chosen based on Akaike Info Criterion (AIC). *F*-statistic for 10 percent critical value bounds is (2.72, 3.77), which is taken from Table CI in Pesaran et al. (2001).

Table 3. Coefficient Estimates of Exchange Rate and Error-Correction Terms of the Reduced Trade Balance Model.

Products	Lag Order of Exchange Rate						
	0	1	2	3	4	5	EC_{t-1}
Bulk	−0.56	−0.58	−0.63	−1.60	−1.47**	−1.57*	−0.81**
	(−0.64)	(-0.67)	(−0.78)	(−0.77)	(−2.22)	(−1.95)	(−3.15)
High-Value	0.37	0.06	0.60	−0.57	0.98**		−0.29*
	(1.00)	(0.14)	(1.37)	(−1.45)	(2.75)		(−2.05)
Combined	0.25	−0.24	−0.40	0.69			−0.80**
	(0.53)	(−0.59)	(−1.27)	(1.86)			(−3.91)

Note: ** and * denote significance at the 5 percent and 10 percent levels, respectively. Parentheses are *t*-statistics. EC_{t-1} refers to the error correction term.

Table 4. Estimated Reduced-Form Equations for U.S. Agricultural Exports, Imports, and Trade Balance, Annual Data, 1976-2012

	Export Value			Import Value			Trade Balance (Export Value/Import Value)		
	Bulk	High Value	Bulk & High Value	Bulk	High Value	Bulk & High Value	Bulk	High Value	Bulk & High Value
Exchange Rate	1.19** (3.72)[a]	0.73** (3.40)	1.72** (3.60)	−0.00 (−0.00)	−0.39 (−1.34)	−0.54* (−2.09)	1.96 (1.28)	1.62** (2.88)	1.88** (4.96)
U.S. Income	−1.41 (−1.70)	−0.26 (−0.71)	0.23 (0.49)	0.07 (0.04)	−0.22 (−0.50)	−0.60 (−1.71)	−0.07 (−0.03)	0.27 (0.28)	0.18 (0.48)
Foreign Income	3.57* (2.48)	0.16 (0.31)	1.38 (1.38)	0.32 (0.18)	2.36 (1.53)	3.63** (3.16)	0.21 (0.08)	−0.40 (−0.31)	−1.32** (−2.57)
D1	0.01 (0.11)	−0.03 (−0.54)	−0.15 (−1.58)	−0.55 (−1.38)	0.05 (0.71)	0.11 (1.61)	0.77 (1.53)	−0.18* (−1.85)	−0.21** (−2.56)
D2	0.03 (0.32)	−0.00 (−0.03)	−0.03 (−0.49)	−0.46* (−2.09)	−0.04 (−0.74)	−0.01 (−0.36)	0.43* (1.84)	0.04 (0.50)	0.08 (1.37)
D3	0.10 (0.85)	0.12* (2.11)	0.12 (1.49)	0.06 (1.16)	−0.02 (−0.32)	0.01 (0.12)	−0.04 (−0.20)	0.03 (0.28)	0.06 (0.88)
D4	0.10 (0.80)	0.04 (0.65)	0.03 (0.50)	0.04 (0.52)	0.07 (1.76)	0.15** (3.47)	−0.04 (−0.20)	−0.06 (−0.93)	−0.04 (−0.59)
R-square	0.84	0.80	0.85	0.79	0.92	0.97	0.87	0.90	0.91
D. W.	1.96	2.24	2.01	2.20	2.18	2.44	2.57	2.56	2.60
AIC	−1.72	−2.91	−2.48	−0.62	−3.85	−4.57	−0.85	−3.24	−2.99
SIC	−1.13	−2.24	−1.84	0.15	−2.93	−3.43	0.12	−2.23	−2.18

[a] Number in parenthesis is asymptotic *t*-ratio. ** and * denote significance at the 5 percent and 10 percent levels, respectively. Since the model is estimated in double-log form, the coefficients of the exchange-rate and income variables are elasticity.

Table 5. *Wald* tests to determine whether bulk and high-value products can be aggregated				
Model	Null Hypothesis	Computed *Chi-square*	Probability	Result
Export Value	Coefficients of Bulk and High Value Equations are Equal	127.4	0.00	Reject at 5% probability level
Import Value	Coefficients of Bulk and High Value Equations are Equal	101.9	0.00	Reject at 5% probability level
Trade Balance	Coefficients of Bulk and High Value Equations are Equal	165.7	0.00	Reject at 5% probability level

Table 6. *F*-tests to determine whether recession effects are jointly significant			
Item	Computed *F*-Statistic[a]	Probability	Result
Export Value:			
Model A[b]	0.32	0.86	Fail to reject
Model B	1.39	0.29	Fail to reject
Model C	1.74	0.19	Fail to reject
Import Value:			
Model A	1.81	0.20	Fail to reject
Model B	1.28	0.35	Fail to reject
Model C	3.30	0.08	Reject at 10% probability level
Trade Balance:			
Model A	0.96	0.47	Fail to reject
Model B	1.40	0.30	Fail to reject
Model C	3.56	0.03	Reject at 5% probability level

[a]The *F*-statistic is computed under null hypothesis that the coefficients of the dummy variables for the four recessionary periods are jointly zero.
[b]Models A, B, and C refer to bulk, high value, and combined bulk and high-value products, respectively.

Appendix

Given the assumptions stated in the test, the structural model consists of seven equations:

(A1) $$Q_d = D(P_d, Y_d)$$

(A2) $$Q_x = X(P_f, Y_f)$$

(A3) $$Q_s = S(P_d)$$

(A4) $$Q_m = M(P_f)$$

(A5) $$P_d = P_f \cdot e$$

(A6) $$Q_s + Q_m = Q_d + Q_x$$

(A7) $$TB = \frac{P_f Q_x}{P_d Q_m} = \frac{Q_x}{Q_m \cdot e}.$$

The as yet undefined variables Q_s and Q_d are the quantities produced and consumed in the home market. The model consists of seven endogenous variables (Q_d, Q_x, Q_s, Q_m, P_d, P_f, TB) and three exogenous variables (Y_d, Y_f, e).

The structural model in proportionate change form is

(A8) $$Q_d^* = \eta_d P_d^* + \gamma_d Y_d^*$$

(A9) $$Q_x^* = \eta_x P_f^* + \gamma_x Y_f^*$$

(A10) $$Q_s^* = \varepsilon_d P_d^*$$

(A11) $$Q_m^* = \varepsilon_m P_f^*$$

(A12) $$P_d^* = P_f^* + e^*$$

(A13) $$k_s Q_s^* + k_m Q_m^* = k_d Q_d^* + k_x Q_x^*$$

(A14) $$TB^* = Q_x^* - Q_m^* - e^*.$$

The import demand curve corresponding to this model may be obtained by substituting (A8) – (A10) and (A12) into (A13)

(A15) $$Q_m^* = \eta_m P_d^* + \left(\frac{k_d\gamma_d}{k_m}\right) Y_d^* + \left(\frac{k_x\gamma_x}{k_m}\right) Y_f^* - \left(\frac{k_x\eta_x}{k_m}\right) e^*$$

where

(A16) $$\eta_m = \frac{k_d\eta_d + k_x\eta_x - k_s\varepsilon_d}{k_m} < 0$$

is the import demand elasticity.

Setting (A15) equal to (A11) and reusing (A12) gives the reduced-form equations for domestic and foreign prices

(A17) $$P_d^* = \left(\frac{k_d\gamma_d}{\varepsilon-\eta}\right) Y_d^* + \left(\frac{k_x\gamma_x}{\varepsilon-\eta}\right) Y_f^* + \left(\frac{k_m\varepsilon_m - k_x\eta_x}{\varepsilon-\eta}\right) e^*$$

(A18) $$P_f^* = \left(\frac{k_d\gamma_d}{\varepsilon-\eta}\right) Y_d^* + \left(\frac{k_x\gamma_x}{\varepsilon-\eta}\right) Y_f^* + \left(\frac{k_d\eta_d - k_s\varepsilon_d}{\varepsilon-\eta}\right) e^*$$

where $\varepsilon > 0$ and $\eta < 0$ are as defined in the text. The reduced-form equations for exports and imports are obtained by substituting (A18) into (A9) and (A11)

(A19) $$Q_x^* = \left(\frac{\eta_x k_d\gamma_d}{\varepsilon-\eta}\right) Y_d^* + \left(\frac{(\varepsilon - k_d\eta_d)\gamma_x}{\varepsilon-\eta}\right) Y_f^* + \left(\frac{\eta_x(k_d\eta_d - k_s\varepsilon_d)}{\varepsilon-\eta}\right) e^*$$

(A20) $$Q_m^* = \left(\frac{\varepsilon_m k_d\gamma_d}{\varepsilon-\eta}\right) Y_d^* + \left(\frac{\varepsilon_m k_x\gamma_x}{\varepsilon-\eta}\right) Y_f^* + \left(\frac{\varepsilon_m(k_d\eta_d - k_s\varepsilon_d)}{\varepsilon-\eta}\right) e^*.$$

The reduced-form equation for trade balance is obtained by substituting (A19) and (A20) into (A14)

(A21) $$TB^* = \left(\frac{(\eta_x-\varepsilon_m)k_d\gamma_d}{\varepsilon-\eta}\right) Y_d^* + \left(\frac{(\varepsilon - k_d\eta_d - k_x\varepsilon_m)\gamma_x}{\varepsilon-\eta}\right) Y_f^* + \left(\frac{(\eta_x-\varepsilon_m)(k_d\eta_d - k_s\varepsilon_d)}{\varepsilon-\eta} - 1\right) e^*$$

Equation (A16) implies

(A22) $$k_m\eta_m = k_d\eta_d + k_x\eta_x - k_s\varepsilon_d \Rightarrow (k_d\eta_d - k_s\varepsilon_d) = (k_m\eta_m - k_x\eta_x) < 0.$$

Substituting (A22) into (A21) yields

(A23) $$TB^* = \overbrace{\left(\frac{(\eta_x-\varepsilon_m)k_d\gamma_d}{\varepsilon-\eta}\right)}^{-} Y_d^* + \overbrace{\left(\frac{(\varepsilon - k_d\eta_d - k_x\varepsilon_m)\gamma_x}{\varepsilon-\eta}\right)}^{?} Y_f^* + \overbrace{\left(\frac{(\eta_x-\varepsilon_m)(k_m\eta_m - k_x\eta_x)}{\varepsilon-\eta} - 1\right)}^{?} e^*.$$

If import supply is perfectly elastic, (A23) reduces to

$$\text{(A24)} \qquad TB^* = \overbrace{\left(\frac{-k_d\gamma_d}{k_m}\right)}^{-} Y_d^* + \overbrace{\left(\frac{(k_m-k_x)\gamma_x}{k_m}\right)}^{?} Y_f^* + \overbrace{\left(\frac{(k_x\eta_x-k_m\eta_m)}{k_m}-1\right)}^{?} e^* \qquad (\varepsilon_m=\infty).$$

The reduced-form equations for the exported value $V_x^* = (P_d^* + Q_x^*)$ and imported value $V_x^* = (P_d^* + Q_m^*)$ are obtained by adding together (A17) and (A19) and (A20) to yield

$$\text{(A26)} \qquad V_x^* = \overbrace{\left(\frac{(1+\eta_x)k_d\gamma_d}{\varepsilon-\eta}\right)}^{?} Y_d^* + \overbrace{\left(\frac{(k_x+\varepsilon-k_d\eta_d)\gamma_x}{\varepsilon-\eta}\right)}^{+} Y_f^* + \overbrace{\left(\frac{k_m\varepsilon_m-\eta_x(k_x+k_s\varepsilon_d-k_d\eta_d)}{\varepsilon-\eta}\right)}^{+} e^*$$

$$\text{(A27)} \qquad V_m^* = \overbrace{\left(\frac{(1+\varepsilon_m)k_d\gamma_d}{\varepsilon-\eta}\right)}^{+} Y_d^* + \overbrace{\left(\frac{(1+\varepsilon_m)k_x\gamma_x}{\varepsilon-\eta}\right)}^{+} Y_f^* + \overbrace{\left(\frac{\varepsilon_m(k_m-k_s\varepsilon_d+k_d\eta_d)-k_x\eta_x}{\varepsilon-\eta}\right)}^{?} e^*.$$

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